UDC 666.29.041:66.043.1:620.193.2

EVALUATION OF CORROSION RESISTANCE OF REFRACTORY MATERIALS IN FURNACES FOR MELTING FRIT GLAZES

B. L. Krasnyi,[1] V. P. Tarasovskii,[1] and A. L. Kuteinikova[1]

Translated from Steklo i Keramika, No. 9, pp. 26 – 27, September, 2005.

The corrosion resistance of refractories to frit melts applied at the Velor Ñompany (city of Orel) are investigated. Based on the results of the study, it is proposed to replace the refractory MKS, which is currently used in furnaces for melting frit glazes, by the refractory material KMTs that is more resistant to frit melts.

The quality of product, the campaign duration, and the efficiency of glass-melting tank furnaces to a large extent depend on the type of refractories used in their brickwork. High-quality refractories significantly decrease the quantity of defects (nonmelted frit, presence of inclusions, etc.) and make it possible to melt frit at a higher temperature, which, in turn, as an essential prerequisite for raising the furnace efficiency. Even though the cost of refractories in this case may grow perceptibly, the improved quality of refractories eventually yield more significant savings.

One of the most important properties of refractory materials used to line furnaces for melting frit glazes is their corrosion resistance to aggressive melts. Corrosion is a complex phenomenon depending on the physicochemical, structural, and texture specifics of refractories, on the technological and design parameters of the furnace, and on the melt composition [1]. Therefore, the choice of refractories to be used as lining in furnaces for melting frit glazes can be made only based on experiments determining corrosion resistance of refractories in frit melts.

Our study gives the results of analyzing corrosion resistance of refractories in frit melts used at the Velor Company (city of Orel). Certain physicochemical properties of frits are presented in Table 1.

Refractory brick MKS-72 (GOST 24704–94) used at the Velor company for furnace lining soon becomes destroyed under the effect of aggressive melt. The service of the furnace between repairs does not exceed one year.

It is known that the higher is the content of zirconium dioxide in refractories, the higher their corrosion resistance. As alternatives to refractory MKS-72, we have chosen refractories produced by the Bakor Scientific Technical Center according to TU 1562-061-11773998-2003 and TU 1594-043-17733998-1997. The physicochemical properties of these refractories are shown in Table 2.

[1] Bakor Scientific Technical Center, Russia.

TABLE 1

Parameter*	Frit		
	SC	MT	BTM
Acidity coefficient	1.1134	1.2746	2.0000
Fusibility	0.532	0.477	0.590
Melting temperature, °C	997	1043	917

* Numerical values of acidity coefficient, fusibility, and melting temperature are derived by calculations [2, 3].

TABLE 2

Parameter	Refractory		
	KMTs	BKT	MKS
Chemical composition, %:			
Al_2O_3	≥ 82.5	≥ 53.0	≥ 72.0
ZrO_2	≥ 10.0	≥ 28.0	–
Fe_2O_3	≤ 0.3	–	≤ 1.5
SiO_2	The rest	≤ 16.0	The rest
$Na_2O + K_2O + Fe_2O_3$	–	≤ 3.0	–
Apparent density, g/cm^3	3.3	≥ 2.9	–
Open porosity, %	≤ 17.0	≤ 15.0	20.0
Compressive strength, MPa	> 80.0	≥ 75.0	≥ 40.0
Thermal conductivity at 1000°C, W/(m · K)	1.75	3.45	–
Heat resistance (1000°C – water), thermal cycles	50	≥ 4	3*
Thermal expansion at 1000°C, %	0.75	0.40	–

* 1300°C – water.

0361-7610/05/0910-0287

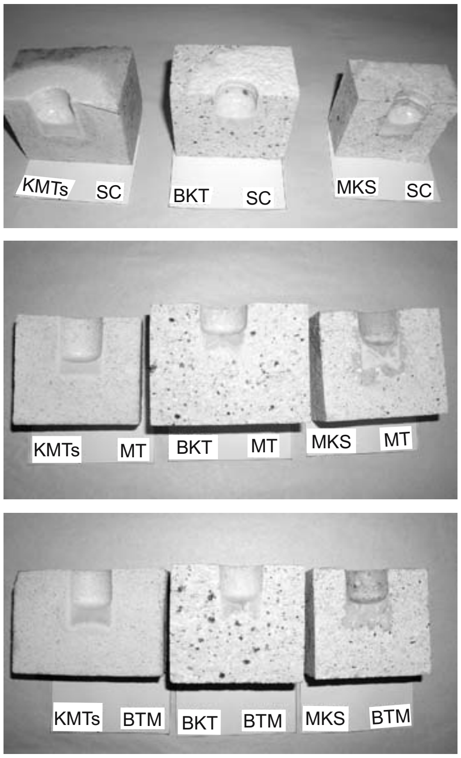

Fig. 1. Samples of refractory materials after testing with frit melts SC, MT, and BTM.

The corrosion resistance of refractory materials in frit melt was estimated by the static method [4] according to the procedure developed at the Bakor Center: “Method for determining corrosion resistance of refractories and ceramics in glass, glaze, and enamel melts (the crucible method). MI 11773998-27-2004.” The testing schedule is as follows: heating samples at the rate of 400 – 450 K/h to a temperature of 1400°C, exposure for 7 h, and cooling samples together with the furnace. Figure 1 shows samples after testing. Since frits used in the experiments have different chemical compositions and, accordingly, different physicochemical characteristics (melting point, surface tension coefficient, contact wetting angle), their interaction with refractories is different as well.

It should be first noted that due to corrosion the diameter of an opening in the sample made of refractory MKS has increased (from 25.8 to 26.8 mm). The diameter of openings in the samples made of refractories KMTs and BKT has not changed. Second, all materials considered have become impregnated with frit melts. To estimate the interaction of refractory materials with frit melts, the samples were subjected to petrographic analysis, whose results are listed in Table 3.

The analysis of results suggests the following conclusions:

– refractory material MKS currently used as tank furnace lining has low corrosion resistance in the frit melts used in testing;

TABLE 3

<table>
<tr><th rowspan="2">Refractory</th><th colspan="3">Frit</th></tr>
<tr><th>SC</th><th>MT</th><th>BTM</th></tr>
<tr><td rowspan="5">KMTs</td><td>n_{fr} = 1.537 (homogeneous)*</td><td>n_{fr} = 1.550 – 1.570</td><td>n_{fr} = 1.516 – 1.519</td></tr>
<tr><td colspan="3">Refractory material is impregnated with frit melt along its pore structure: the white edge along the inner surface of the crucible</td></tr>
<tr><td>Impregnation depth 675 μm</td><td>Impregnation depth 250 μm</td><td>Impregnation depth 625 μm</td></tr>
<tr><td colspan="3">There is no chemical reaction between frit melt and refractory material</td></tr>
<tr><td>The beige-color zone around the inner surface of the crucible is not identified petrographically</td><td>The beige-color zone around the inner surface of the crucible is absent</td><td>The beige-color zone around the inner surface of the crucible is not identified petrographically</td></tr>
<tr><td rowspan="4">BKT</td><td>n_{fr} = 1.555</td><td>n_{fr} = 1.550 – 1.570</td><td>n_{fr} = 1.513</td></tr>
<tr><td colspan="3">Interaction between refractory and frit starts at the stage of frit melting</td></tr>
<tr><td colspan="3">Chemical reaction between the highly dispersed component of the refractory and the frit met is very intense and leads to the formation of new crystalline compounds containing mixture components: ZnO, CaO, Al_2O_3, etc.</td></tr>
<tr><td>The interaction between the refractory and the frit melt is extended to entire refractory, intense corrosion of Al_2O_3 grains and, to a lesser extent, of ZrO_2 grains is observed</td><td>The interaction between the refractory and the frit melt is extended to entire refractory, corrosion of Al_2O_3 and ZrO_2 grains is observed</td><td>The interaction between the refractory and the frit melt is extended to entire refractory, very intense corrosion of Al_2O_3 and ZrO_2 grains is observed</td></tr>
<tr><td rowspan="2">MKS</td><td>n_{fr} = 1.550</td><td>n_{fr} = 1.550 – 1.570</td><td>n_{fr} = 1.510 – 1.513</td></tr>
<tr><td>The viscous frit melt at the moment of fusion has reacted in the surface layer with SiO_2 contained in the highly dispersed component of the refractory. As a consequence, a layer of crystallized (devitrified) frit has been formed, through which the refractory and the frit continue interacting, but such interaction is slow</td><td colspan="2">Before the beginning of frit melting, its components start reacting with SiO_2 contained in the highly dispersed component of the refractory. The process intensifies in the course of frit melting and the refractory, like a sponge, absorbs the frit melt. Dark gray zones are zones of recrystallization of mullite $3Al_2O_3 \cdot 2SiO_2$, huge mullite grains are formed (250 – 350 μm), but the zones themselves are loose.</td></tr>
</table>

* n_{fr}) refractive index of frit.

– refractory BKT has higher corrosion resistance in frit melts than refractory MKS;

– no interaction has been registered between the refractory material KMTs and frit melt, even extending exposure duration to 31 h.

The refractory KMTs is recommended for industrial testing as corrosion-resistant material to line tank furnaces for melting frit glazes.

The authors are grateful to N. A. Popova for petrographic analysis of samples and discussion of results.

REFERENCES

1. O. N. Popov, *Corrosion and Service of Refractory Materials in Glass-Melting Tank Furnaces under High-Temperature Glass Melting* [in Russian], VNIIÉSM, Moscow (1974).
2. A. A. Appen, *Chemistry of Glass* [in Russian], Khimiya, Leningrad (1974).
3. I. I. Moroz, M. S. Komskaya, and M. G. Sivchikova, *Reference Book on Porcelain and Faience Industry, Vol. 1* [in Russian], Legkaya Industriya, Moscow (1976).
4. A. N. Alekseeva and E. S. Borisovskii, “Methods for determining glass resistance of refractories,” *Ogneupory*, No. 3, 56 – 60 (1966).